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An overview of renewable energy potential and utilisation in Australia

Alireza Bahadori [a,*], Chikezie Nwaoha [b], Sohrab Zendehboudi [c], Gholamreza Zahedi [d]

[a] Southern Cross University, School of Environment, Science and Engineering, Lismore, NSW, Australia
[b] Independent Consultant, 10a Lake Nwaebere Street, Aladinma, Owerri, Nigeria
[c] Department of Chemical Engineering, The University of Waterloo, Waterloo, ON, Canada
[d] Process Systems Engineering Centre (PROSPECT), Faculty of Chemical Engineering, Universiti Teknologi Malaysia, UTM, Johor, Malaysia

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ABSTRACT

As concerns about rising fossil fuel prices, energy security, and climate change increase, renewable energy can play a key role in producing local, clean, and inexhaustible energy to supply Australia's growing demand for electricity, heat, and transportation fuel. Renewable energy is an essential part of Australia's low emissions energy mix and this energy is important to its energy security. Australia has some of the best renewable energy resources in the world. This paper will focus on the impact of these renewable energies in Australia. This study shows that Australia has the potential to secure its long term energy future through focus and encouragement on increasing utilisation of renewable energy.

Contents

1. Introduction

Current power systems create environmental impacts as well as contributing to global warming due to their utilisation of fossil fuels, as carbon dioxide (CO_2) is emitted into the atmosphere [1].

* Corresponding author. Tel.: +61 2 6626 9412.
E-mail address: Alireza.bahadori@scu.edu.au (A. Bahadori).

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Though these fossil fuels have provided us with economical and convenient energy sources but their production and use has also come with a huge environmental cost (greenhouse gas emissions), which is now a global concern [1–3]. In contrast to fossil fuels, renewable energy is starting to be used as the panacea for solving climate change or global warming problems.

If we do not reduce carbon pollution, the world risks serious effects from climate change. Global average temperatures could increase by up to 6.4 °C above 1990 temperatures by 2100. Sea levels are estimated to rise by between 0.5 and 1 m by 2100 from 2000 levels and the acidity of the world's oceans will increase significantly [2].

Fossil fuels are a non-renewable energy resource and the race now is on to find an alternative. With this regards, there is a global movement towards the generation of renewable energy to help meet our increased energy needs. Renewable energy sources present the potential of energy production with a minimum impact on the environment, particularly in relation to greenhouse gas emissions [3].

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, hydropower, geothermal resources, and biofuels derived from renewable resources [1–3].

In Australia, Government ratified the Kyoto Protocol agreeing to reduce greenhouse gas emissions by 60 per cent on 2000 levels by 2050 [3]. The renewable energy and energy efficiency sector will play a critical role in transforming the Australian economy. Australia has some of the best renewable energy resources in the world and the Australian Government is committed to working with the industry to ensure it can reach its full potential [4–6]. In Australia more than $5.2 billion was invested in renewable energy during the 2010–2011 financial year, including approximately $4 billion on household solar power alone. This is more than 60 per cent higher than during 2009 [4].

This paper will focus on the impact of these renewable energies in Australia. It includes the development of Solar Photovoltaic (PV), Wind turbines, Solar thermal, Geothermal, Bioenergy, Hydro-electric power, Marine Energy capacities in Australia.

2. Australia's pollution profile

Global warming and the threat of climate change caused by large carbon emissions have created interest in Australia in the move to a more sustainable energy mix. Renewable energy is the only viable option to reduce emissions, while at the same time providing Australia's energy needs [7].

Already, Australia is taking some important actions to reduce their carbon pollution. Yet even with these existing measures in place, Australia′s carbon pollution is still growing by almost 2 per cent each year. This is why the Government has adopted a comprehensive plan to secure a clean energy future [2].

Australia is a hot and dry continent. This means that amongst the world's developed countries, Australia faces acute risks. Studies indicate that warming of more than 2 °C will overwhelm the capacity of many of our natural ecosystems to adapt. With that level of warming, for instance, the survival of the Great Barrier Reef will be in jeopardy as higher ocean temperatures and acidity levels cause major changes to coral reefs [4–7].

Australia's carbon pollution represents 1.5 per cent of global emissions of greenhouse gases. That makes them one of the top 20 polluting countries in the world [7]. In fact, Australia produces more carbon pollution per head of population than any developed country in the world, more even than the world's biggest economy, the United States [4–7].

The availability of cheap and abundant coal has made Australia depend heavily on coal to meet its electricity needs thereby making it the largest source of carbon pollution. Electricity generation is responsible for just over a third of Australia's total carbon pollution. Direct fuel combustion – reflecting the use of gas and other fuels in industry and homes – accounts for another 15 per cent. Transport and agriculture each contribute around another 15 per cent. The remaining sources are 'fugitive' emissions – mainly the methane and carbon dioxide which escapes into the atmosphere when coal is mined and gas is produced – along with pollution from industrial processes and decomposition of waste in landfills and elsewhere.

Trees absorb carbon dioxide, so when land is cleared there is an increase in carbon pollution and when vegetation grows there is a decrease. The net impact of these sources – deforestation, reforestation and afforestation – contributes 3 per cent of Australia's total carbon pollution States [7].

With Figs. 1 and 2, Australia's emissions are projected to continue to grow by almost 2 per cent a year. Even taking into account existing climate change policies such as the Renewable Energy Target and the Carbon Farming Initiative, emissions are expected to be around 22 per cent higher than 2000 levels in 2020 [4–7].

The Government has committed to reduce carbon pollution by 5 per cent from 2000 levels by 2020 irrespective of what other countries do, and by up to 15 or 25 per cent depending on the scale of global action. These targets will require cutting expected pollution by at least 23 per cent in 2020 [4–7].

As concerns over climate change mount, there is increased movement towards less carbon- intensive methods of electricity generation, including renewable energy, as well as renewed interest in the demand-side of electricity markets [8].

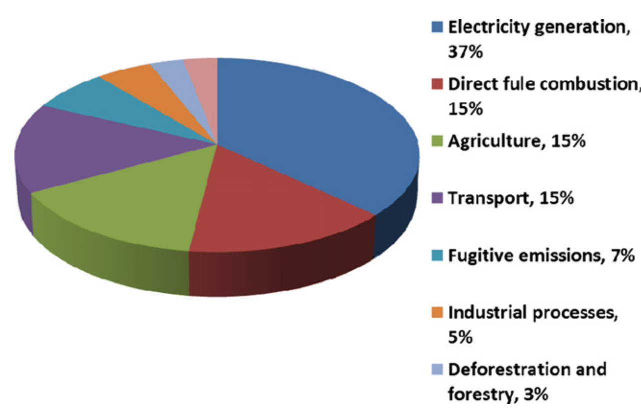


Fig. 1. Australia's carbon pollution profile, *source*: 2009 emissions from the National Greenhouse Gas Industry and cited in Commonwealth of Australia, 2011 [3].

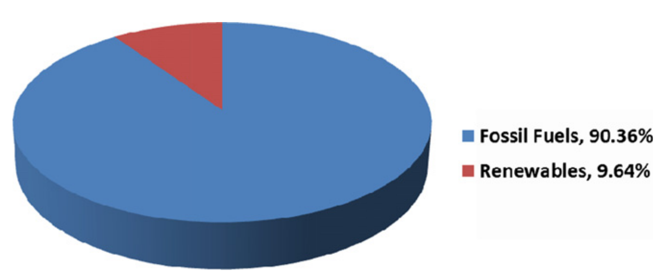


Fig. 2. Australia's estimated annual electricity generation (Clean Energy Council, 2011) [4–6].

3. Australia and its renewable energies

The renewable energy generated during the 12 months to the end of September 2011 produced enough electricity to power the equivalent of more than 4 million average Australian households [4–6].

Hydro electricity accounted for two thirds of the renewable energy generated during this period, rising from its more modest contribution in recent years. Rainfall continues to be one of the strongest influences on the country's clean energy generation, followed by wind [4–6].

Although there was significantly more wind power generated compared to the year before, its relative contribution fell slightly (21.9 per cent) due to the increased contribution by the hydro sector. Wind was followed by bioenergy (8.5 per cent) and solar photovoltaic (PV) power (2.3 per cent) [4–6].

Away from the southern and eastern coasts, the population of Australia is spread very thinly. In the interior, evaporation vastly exceeds rainfall, temperatures can reach 45–50 °C, fresh surface water is rare and the soil is old and impoverished [9]. It is, nevertheless, home to many small Aboriginal communities and enormous pastoral stations. In this environment, both sectors are very difficult to service particularly in overcoming the vast distances between population centres [9]. The high cost of transport and of fossil fuels and the isolation of the communities are conditions which favour renewable energy [9]. Fig. 3 shows the details of estimated percentage contribution of each technology to renewable generation in Australia.

3.1. Solar photovoltaic (PV)

In one form or another, solar power has been around for thousands of years. As a renewable source of free, green energy, technology has found a way of harnessing the sun's energy via solar panels which are used either to generate electricity (solar photovoltaics) [10,11].

This technology provides a load factor of 15–20 per cent. Solar photovoltaic cells are best for supplying peak demands in the middle of the day, but are less effective in managing the evening peak [10–12].

Depending on feed-in tariffs, currently photovoltaics require between 4 and 10 years to recoup their investment and 2–3 years to recoup the energy used in their manufacture [12].

Current costs are around $0.20 per kilowatt hour (kW h), but with the new technologies currently under development, generation costs are expected to reduce significantly. Solar photovoltaic systems are suited to domestic grid-connect power applications [10–12].

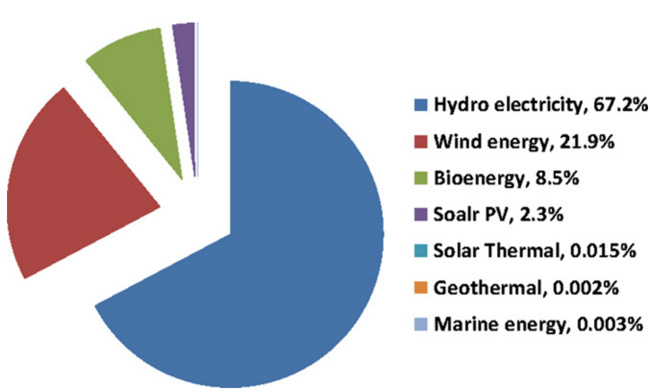


Fig. 3. Australia's estimated percentage contribution of each technology to renewable generation (Clean Energy Council, 2011) [4–6].

The growth of solar power was one of the stories of 2011 following a record year in 2010, when 380 MW of solar power was installed. As at the end of August 2011, 1031 MW of solar power was installed across the country, representing more than half a million household systems [4–6]. This is more than nine times the amount of solar power installed as at the end of 2009 and more than 35 times the total installed just three years ago in 2008. More than 230,000 of these systems were installed in the eight months from January to August 2011 [6,10].

Nationally it is estimated that 8 per cent of all suitable homes are fitted with a solar photovoltaic (PV) power system [4–6].

The large uptake of solar power has helped to drive down costs for consumers, create thousands of industry jobs and make this technology an everyday part of mainstream Australia. The cost of solar PV continues to fall rapidly and is expected to reach the cost of grid electricity towards the middle of the decade [4–6,10–12].

The growth of solar hot water has been more modest over the last couple of years. The generous government support available for solar PV systems has led many customers to choose PV over solar hot water, despite the excellent energy savings available from the latter technology. A national ban on the replacement of electric hot water systems from 2012 is expected to give the solar hot water industry a welcome boost [5,6,10,11].

The number of Australian households with solar panels has increased more than 35 times over the last 3 years [4,10].

There were 513,585 solar PV systems installed at the end of August 2011. Approximately 430,000 of these were installed during the last two years. More than 6 per cent of Australian houses have now installed solar power and the number of accredited solar installers across the country has increased by six times in the last three years to more than 4000 [4–6]. Data from the Office of the Renewable Energy Regulator released by the Clean Energy Council in February 2011 showed that Australians from all walks of life were embracing this technology, including those from so called mortgage belt and retirement suburbs across the country.

The cost of solar power continues to fall and many analysts expect it to meet the retail cost of mainstream electricity around the middle of the decade [4–6,10].

With all these developments, solar PV accounts for 2.3 per cent of total clean energy generation in Australia [10].

3.2. Wind turbines

Wind energy is abundant and easily accessible in many parts of the world, which is why it is one of the most advanced and commercially available renewable energy technologies. Western Australia has a good wind resource and more so in the summer months when energy demand is at a peak. Wind power is the conversion of wind energy into useful forms, such as electricity, using wind turbines [13]. The ease with which wind energy is integrated into electricity grids and the short construction period of wind farms makes the use of wind energy one of the cheaper renewable energy technologies [3,13].

Though variable, wind turbines achieve a capacity factor (the ratio of average output power to the turbine's rated or maximum power) of up to 50 per cent in Australian wind farms, and require less than 3 to 6 months to recoup the energy used in their manufacture Dopita and Williamson [12]. Currently, large wind turbines are cheaper than any other renewable energy source, and under the mandatory renewable energy target (MRET) they compete head-to-head with coal-fired electricity generation at current costs. As fossil fuels are anticipated to incorporate their environmental costs with the introduction of an emissions trading scheme, the competitive position of wind turbines should continue to strengthen. Subject to amenity and aesthetic considerations, there

are significant opportunities for small- and medium-sized turbines to be installed in urban and semi-urban areas such as sporting fields, parks, shopping centre car parks and industrial areas [12,13].

There were modest gains for industrial-scale renewable energy over the last year, repeating the pattern from the year before. A dozen large-scale renewable energy power plants have become operational since October 2010, though most of the 400 MW in new generating capacity came from three wind farms and a hydro upgrade. Although this figure is higher than in 2010, it is still well down on the 993 MW of power that came online in 2009 [4–6,13].

In the past year wind power generated over 6400 GW h of electricity, which was enough to power over 900,000 homes [4–6].

Australia currently has 1188 wind turbines and 57 operating wind farms, including one small wind farm located in the Australian Antarctic Territory. The amount of wind power in Australia has grown by an average of 35 per cent per year over the past five years, and the efficiency and power output of turbines are evolving quickly [4–6].

A report prepared by Garrad Hassan for the Clean Energy Council in 2011 predicted that there would be approximately 6.9 GW of wind power built under the Renewable Energy Target by 2020. This would be delivered from approximately 2000–2500 wind turbines, depending on their size and power output [4–6,13]. Acciona's Waubra wind farm north-west of Ballarat in Victoria is currently the largest in the country, with 128 turbines spread out over 173 square kilometres [5].

Wind energy accounts for 22 per cent of total clean energy generation in Australia [4–6].

Finally, in Australia, the wind turbine market is expected to benefit from Australia's new push for sustainable energy. It is expected that wind energy will provide the largest share of Australia's targeted 20 per cent renewable energy by 2020 [12,13].

Fig. 4 indicates that the majority of the coast line at lower latitudes produces between 8 and 10 m/s of wind. Generally 8 m/s is suitable for a wind farm though a more detailed statistical analysis must be undertaken to determine the statistical properties of the wind [14]. In areas with suitable wind profiles a wind farm is an excellent method for generating substantial amounts of energy.

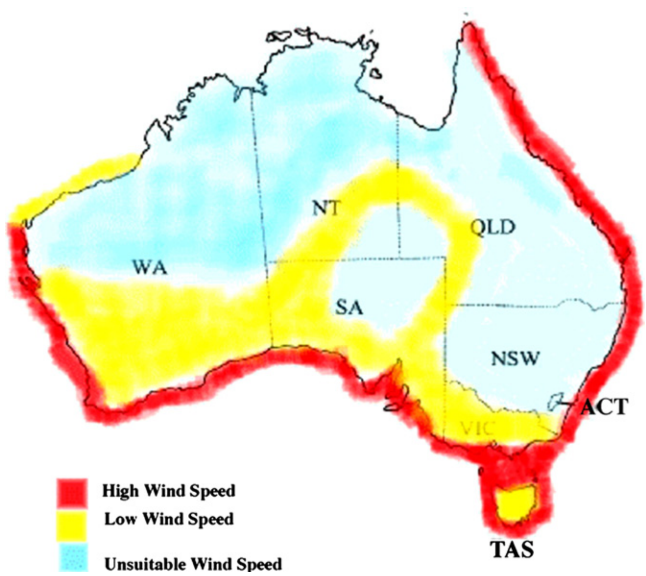


Fig. 4. Australia potential wind speed (Department of Resources Energy and Tourism [21] as cited in Yusaf et al. [14]).

3.3. Solar thermal

Solar thermal technology refers to the capture and utilisation of solar energy for use in heat or electricity production. Solar thermal electricity is generated by concentrating incoming sunlight and trapping its heat. The heat can be used as an energy source in itself, or an engine/steam turbine can convert the heat to electricity. Large-scale solar thermal trough systems were established in California over 20 years ago and this technology is enjoying resurgence. Combined with either heat storage technology or steam boiler back up these systems can provide peak or base load power. In solar thermal air heating and cooling technology, solar heat is utilised to heat homes and buildings. Roof cladding and walls provide the solar heat or external panels can be used. Air cooling is possible using the same system to ventilate overnight [3].

With appropriate energy storage, this technology offers potential load factors close to 100 per cent, and is ideally suited for base-load power generation. It uses solar concentrators to focus sunlight for electricity generation. To put solar thermal generation systems into perspective, the Sun's energy falling on Australia in one day is equal to half the total annual energy required by the whole world. To power all of Australia's energy needs would require only 0.3 per cent of the land surface to be devoted to solar power generation [10,12].

Australia has the highest average solar radiation per square metre of any continent in the world. The International Energy Agency [15] forecasts that concentrated solar power could provide Australia with 40 per cent of its energy by 2050.

Australia's large-scale solar industry is still in its infancy, despite having access to some of the world's best solar resources. The Australian Government announced the successful applicants to the first round of its $1.5 billion Solar Flagships program in June 2011. The program will deliver the first truly large-scale projects in Australia, building valuable local expertise that will help in the development of future projects [4–6].

In Australia, new policy measures linked to the recent clean energy legislation set the stage for the country to participate in the deployment and improvement of solar thermal generation. For the coming year, it will be critical that at least one project of large scale be financed for deployment by 2015 [4–6,10]. This will enable large-scale solar power to finally be considered as an integral component of the Australian generation portfolio for 2020 and beyond [4,10].

Australia's largest solar plant is a 3 MW facility at Liddell in NSW that utilises solar thermal concentrators.

Currently, Australia has 27 operating plants with 13 under construction [6].

3.4. Geothermal

Geothermal energy is heat energy originating deep in the earth's molten interior. It is responsible for tectonic plates, bubbling mud pools, hot springs, volcanoes and earthquakes. Geothermal energy is a proven resource for direct heat and power generation [3,16].

Alternatively, this relies on producing superheated steam in radioactively heated 'hot rock' granite deposits to generate electricity. This process works best when the substrate rock (approximately 5 km deep) has been heated to over 250 °C [12,16].

Fortunately, Australia has several such deposits, notably in the Cooper and Galilee Basins located close to the boundary of New South Wales, Queensland and the Northern Territory. A 15 cubic kilometre of hot granite at 250 °C has the stored energy equivalent of 20 million barrels of oil [12]. This technology is in development

in Australia by several Australian companies at various levels of operation [16].

Geothermal energy has the potential to play a major role in decarbonising Australia's electricity supply by providing reliable, emission-free power generation. Modelling by ROAM and SKM MMA for the Department of Treasury in 2011 found that geothermal energy could account for between 13 and 23 per cent of our total electricity needs in 2050 [5,16].

Technical and financial challenges have seen the geothermal industry progress slowly in 2011 with just three projects having commenced deep drilling. As of 2011 only one commercial geothermal plant was operating in Australia, at Birdsville in Queensland [4–6]. This challenge has seen geothermal energy contribute just a 0.002 per cent of total clean energy generation in Australia [4–6,16]). Currently there are three geothermal plants under construction [4–6,16].

Geothermal power plants have a number of advantages over other clean technology energies. This is so because, they are unaffected by changing weather conditions and they can work continually day and night. However, costs of utilising this energy are dependent on the depth and temperature of the resources and the size of the project [3].

3.5. Bioenergy

Currently bioenergy amounts to 8.5 per cent of Australia's total renewable generating capacity [4–6].

Bioenergy grew only marginally in 2011, as has been the case for several years now. Nine small projects came online during the last two years [4,5]. The challenging financial environment, the soft price of renewable energy certificates, and the issues with connecting some types of bioenergy to the grid continued to have a negative impact on the development of new bioenergy plants [5,6]. With abundant biomass resource and with the right policy bioenergy will gain a huge boost in the use of bioenergy to assist Australia's transition to a low-carbon economy.

Bioenergy currently generates around 2500 GW h per annum—around one per cent share of total electricity generation [4–6].

3.5.1. Sources

Biomass is any recent organic matter that can be used as fuel. It can be used directly for electricity production, heating, cooking or indirectly by converting it into a liquid or gaseous fuel. Biomass generating plants can produce electricity in a similar way to generating electricity using fossil fuels. In essence, fossil fuels are simply replaced with biomass as a fuel source, creating a cleaner, renewable energy alternative. Biomass offers great potential to replace existing fossil fuel power plants. Transportation and processing costs are key to the price, so biomass power plants must be sited near an ongoing, reliable biomass source. The use of plantation waste for power generation is an efficient waste-disposal process that produces net environmental benefits.

Biomass power systems can be referred to as carbon dioxide/greenhouse neutral, since the plant material absorbs as much carbon dioxide during its life as is released when burnt to produce electricity [3].

3.5.2. Landfill gas

Landfill gas is created when biomass is buried in landfill and over time decomposes creating methane. The methane is captured from the land fill site through a network of underground pipes and used to generate power.

3.5.3. Biomass to methane

Technologies are now being developed to directly decompose biomass, including sewage and city waste, under controlled conditions to ensure greater methane capture rates and to reduce gas escape. Many of these processes result in organic waste suitable for other purposes [3]).

3.5.4. Biofuel

Biofuels are considered an alternative to replacing petroleum gas (gasoline or petrol). The majority of transportation vehicles require high power density provided by internal combustion engines. These engines require clean burning fuels, which are generally in liquid form. Liquids are preferred for transportation fuel as they are portable, they can be pumped and they have high energy density. Bioethanol and biodiesel are currently the two preferred types of biofuels. Production of these biofuels is expected to increase as governments worldwide pass legislation to increase the proportion of biofuels in the overall transportation fuels mix as part of their wider strategies to promote the use of renewable energy [3].

3.6. Hydro-electric power

Hydroelectric power is electricity produced by the movement of water from rivers and lakes driving a water turbine and a generator producing electricity. The majority of hydroelectric power comes from the potential energy of dammed water Bahadori et al. [13]. The energy extracted from the water depends on the volume and the difference in height between the source and the level of the water's outflow. Hydroelectric power is popular as it provides virtually free generation of power once the dam is built. In addition, the power supply is well suited to meet both base load demand and peak power requirements [3].

Increased rain in key catchment areas reinvigorated the nation's hydro electricity generation sector and provided approximately two thirds of the renewable energy produced over the 12 months to 30 September 2011, amounting to 67.2 per cent in electricity generation [4–6].

Most of Australia's suitable hydro electricity resources have already been developed. Work undertaken by hydro operators is generally in developing mini hydro power plants or in upgrading and refurbishing existing hydro power stations. The iconic Snowy river hydro-electric scheme and Tasmania's network of 27 hydro-electric projects provide the majority of the country's hydro power [4–6,18].

Australia's 124 operating hydro power stations produced enough electricity in the past year to power the equivalent of almost 2.8 million average homes. The estimated 19,685 GW h of power was 6.5 per cent of all electricity produced in Australia during this period [4–6,18].

Currently there are seven hydroelectric power under construction [4–6].

Fig. 5 indicates areas of high rainfall suitable for hydro power generation.

3.7. Marine energy

Around 80 per cent of Australia's population lives within 50 km of the coast, placing wave and tidal energy resources close to the area of highest electricity demand [4–6].

Australia's long coastline and proximity to both the tropics and the Southern Ocean mean that there is an enormous energy resource available if we can develop cost-effective technology to harness it.

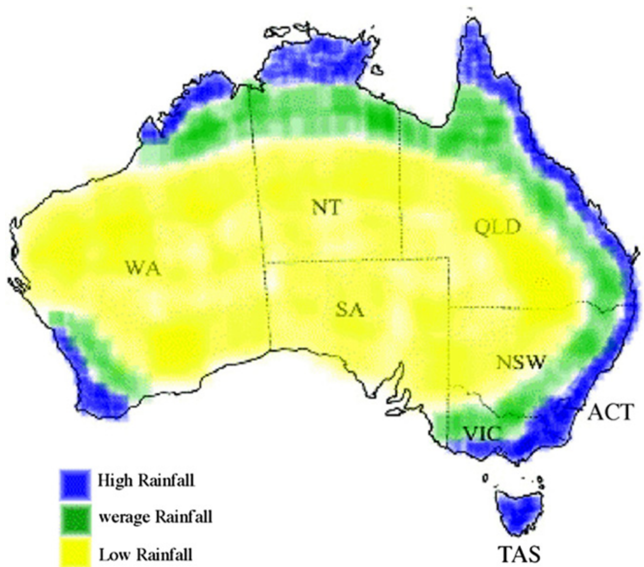


Fig. 5. Average rainfall in Australia (Department of Resources Energy and Tourism [21] as cited in Yusaf et al. [14]).

In 2011 more than 15 companies have been actively investigating wave and tidal energy projects in Australia. Wave resources are mostly being explored along the southern and western coastlines, while the northern coastline is the focus for those exploring tidal resources [4–6].

This accounts for just 0.003 per cent of total clean energy generation, with 2 operating plants and 9 under development [4–6].

4. Challenges of some renewable energies

The development of renewable energy sources is of prime interest of many countries seeking to pursue greenhouse gas emission reduction obligations [17]. The increased use of renewables offers the possibility of not only contributing to emission reduction, but at the same time improving energy supply diversity and security, and developing employment and business in related supply industries [17].

Apart from all these advantages, renewable energy also has some challenges confronting it considering Australia. Since renewable sources fluctuate biannually, as with solar power, or more randomly as with wind power, there are also a number of ways this conversion can be controlled [9]. The plant can be run at a steady rate with the renewable power connected to the town grid so that power can be exported or imported to the plant as required.

The electrical energy can be stored chemically in storage batteries and run at a steady rate, either 24 h per day or run at set hours per day using a smaller bank. The plant can be controlled to only operate when required power levels are available and dump excess power to maintain steady production for interrupted periods, working best with solar power. It can, of course operate using the power as it becomes available but usually needs some internal control to maintain system efficiency [9].

Also, as with all electricity generation, renewable energy power stations must be connected to the transmission network (Network) in order to transmit electricity to the distribution network and to end consumers [8]. Due to Australia's vast geographic area, this will need huge investments in complementary grid and transmission lines [7].

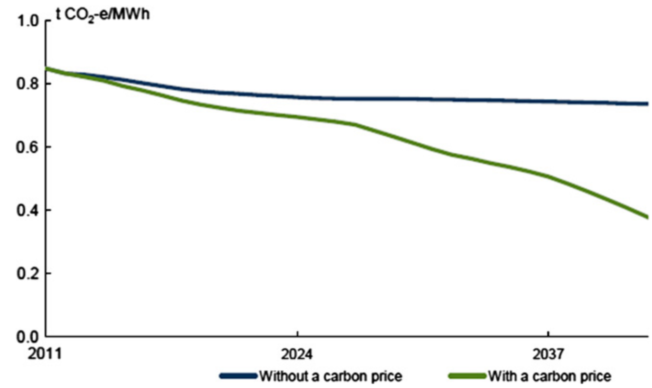


Fig. 6. Emissions intensity of electricity generation with and without a carbon price *Source*: Treasury modelling, 2011, cited in Clean Energy Future 2012 [5].

5. Price for carbon emission: An encouragement towards renewable energy?

Putting a price on carbon pollution is the first element from the Australian Government's plan for a clean energy future [5]. A carbon price is the most environmentally effective and economically efficient way to reduce pollution.

A price on carbon pollution will create a powerful incentive for businesses across the economy to cut their pollution by investing in clean technology and finding more efficient ways of operation. It will ensure that pollution is reduced at the lowest cost to the economy [3]. This carbon pricing mechanism will start with a fixed price on carbon like a tax and will then transition to an emissions trading scheme.

As from 1 July 2012, a fixed carbon price will start at $23 a tonne, to last for three years. From 1 July 2015, the carbon price will be set by the market [4–6].

Households and small businesses will have no direct obligations under the carbon price. Around 500 of the biggest polluters in Australia will be required to pay for their pollution under the carbon pricing mechanism [3]. The 50 largest polluters will be responsible for around 75 per cent of the pollution covered by the carbon pricing mechanism [5].

This carbon price will not be applicable to agricultural emissions or emissions from light on-road vehicles [3].

Every cent raised from a price on carbon will be used to provide tax cuts and increased benefits to households, support jobs in the most affected industries, and build a new clean energy future [5].

At present, low- and zero-pollution generation technologies are more expensive than conventional coal-fired generation—in inverse proportion to their impacts on the atmosphere. A carbon price helps change the balance. It will put an economic premium on releasing less pollution for every megawatt hour of electricity generated. A carbon price will narrow the cost differential between electricity from conventional coal-fired generation technologies compared with electricity from natural gas and renewable sources Fig. 6 [5].

5.1. Economic influence of a carbon price

Treasury modelling (core policy scenario) estimates that under a carbon price [3] Fig. 7:

- Incomes grow: Gross National Income per person increases from today's levels (around $56,000) by around $9000 per

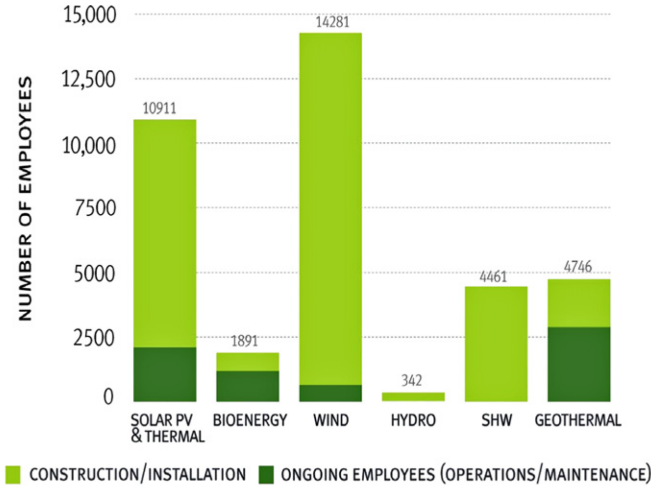


Fig. 7. Estimated numbers of new jobs created in the renewable energy industry by 2030 (cited in Clean Energy Council, 2011) [4–6].

person to 2019–2020. By 2050, the increase is expected to be more than $30,000 per person in today's dollars.

- Jobs grow: national employment increases by 1.6 million jobs by 2020.
- Pollution falls: growth in domestically produced carbon pollution slows.
- Large-scale renewable energy (excluding hydro) is projected to be 18 times its current size by 2050. Total renewable generation (including hydro) will comprise around 40 per cent of electricity generation in 2050.
- Gas-fired electricity increases by over 200 per cent by 2050.

6. Future of renewable energy in Australia

Australia emitted 565 million tonnes of carbon pollution in [3]. On a per person basis, that is the equivalent of every Australian adult driving a medium-sized petrol-powered car almost 200,000 km during the year [3].

The Australian Centre for Renewable Energy (ACRE) was established to promote the development, commercialisation and deployment of renewable energy and enabling technologies and improve their competitiveness in Australia.

ACRE's key objectives are:

- Developing and implementing a funding strategy capable of supporting projects along the innovation chain.
- Encouraging additional investments—including investments from the private sector and state and territory governments.
- Managing the cost effective delivery of government-funded renewable energy and enabling technology programs.
- Providing support and advice to governments, industry and the community on renewable energy and enabling technologies, strategies and related issues when requested.
- Fostering collaboration between governments, industry and the research community on renewable energy projects.
- supporting growth in skills and capacity in renewable technologies for the domestic and international markets.

This has prompted the Australian Government in establishing a commercially oriented Clean Energy Finance Corporation (CEFC) to boost private sector investment in renewable energy and clean energy projects [4–6].

These initiatives will work together with the Government's Renewable Energy Target (RET) and complement the carbon price [4–6].

The Government's plan for a clean energy future represents a historic move to increase Australia's investment in clean technologies, in particular renewable and clean energy technologies and generation.

These transformations in the energy sector will drive around $100 billion in investment in the renewables sector over the period to 2050 [4–6]. The Government's plan to support this investment includes [4–6]:

- Commercialisation and deployment of clean technologies through the commercially oriented $10 billion Clean Energy Finance Corporation.
- Research, development and commercialisation of renewable energy at an early stage through the $3.2 billion Australian Renewable Energy Agency.
- Research and development of clean technologies through the $200 million Clean Technology Innovation Program.
- Increased use of renewable energy through the carbon price and the Renewable Energy Target.

In addition to the above, the Australian government introduced what is called MRET (Mandatory Renewable Energy Target). The objectives of MRET as stated in the Act, are to encourage the additional generation of electricity from renewable sources, reduce emissions of greenhouse gases, and ensure that renewable energy sources are ecologically sustainable (Renewable Energy (Electricity) Act 2001, as cited in Kent and Mercer [19]).

While other countries have adopted somewhat similar schemes, Australia's MRET represents the first genuinely mandatory rather than merely aspirational renewable energy target regime [19].

These measures will provide a disincentive to carbon-intensive electricity generation and likely further increase the utilisation of renewable energy Wright [8]. And these government policies and actions represent the engine room for renewable supply development [20].

7. Conclusion

The secure supply of affordable, reliable, environmentally sustainable energy is essential to Australia's future economic growth and prosperity. Australia's future energy supply will need to have lower greenhouse gas emissions in order to meet the challenges posed by climate change driven by rising levels of carbon dioxide in the Earth's atmosphere.

Renewable energy utilisation supports future energy security, help lower emissions from the energy sector and enables Australia to meet the national renewable energy target of 20 per cent renewable generation by 2020. Australia can be at the leading edge of renewable energy technology. It may also have the potential for sustainable job creation and stimulation of export business opportunities. Government policies are crucial in determining both the rapidity of evolution and the future potential net economic value of the energy future.

The Australian government has encouraged renewable energy by putting a price for carbon pollution. This will in turn encourage large polluters to reduce the greenhouse gases they put into the atmosphere. From the economic stand point, researchers, scientists, investors will venture into finding new less-polluting ways of producing, generating and consuming energy, goods and services.

Through the introduction of the announced Clean Energy Future Package, a carbon price and complementary measures, it is an essential need that the Australian Government supports the development and deployment of clean energy technologies.

Putting all these in place, Australia has the potential to secure its long term energy future through focus and encouragement on increasing utilisation of renewable energy.

References

[1] Shafiullah GM, Amanullah MTO, Shawkat Ali ABM, Jarvis D, Wolfs P. Prospects of renewable energy—a feasibility study in the Australian context. Renewable Energy 2012;39:183–97.
[2] Commonwealth of Australia. 2011. Securing a clean energy future: the Australian Government's Climate Change Plan. Canberra: Department of Climate Change and Energy Efficiency. p. 1–135.
[3] Department of Commerce. 2009. Renewable energy and clean technology directory of innovations and capabilities in Western Australia. Government of Western Australia. p. 1–81. Available at: 〈www.commerce.wa.gov.au/renewable-energy〉.
[4] Clean energy council, clean energy Australia report: renewable energy year in review. Available at: 〈www.cleanenergycouncil.org.au〉. 2011; p. 1–72.
[5] Clean Energy Future, 2012. Clean energy Australia. Available at: 〈http://www.cleanenergyfuture.gov.au/clean-energy-future/our-plan/clean-energy-australia/〉.
[6] Clean Energy Future, 2011. Clean energy Australia: investing in the clean energy sources of the future. Available at: 〈http://www.cleanenergyfuture.gov.au/wp-content/uploads/2011/07/clean-energy-australia.pdf〉.
[7] Effendi P, Courvisanos J. Political aspects of innovation: examining renewable energy in Australia. Renewable Energy 2012;38:245–52.
[8] Wright G. Facilitating efficient augmentation of transmission networks to connect renewable energy generation: the Australian experience. Energy Policy 2012;44:79–91.
[9] Harrison DG, Ho GE, Mathew K. Renewable energy in the outback of Australia. Withlacoochee River Electric Cooperative 1996:776–80.
[10] Bahadori A, Nwaoha C. A review on solar energy utilization in Australia. Renewable & Sustainable Energy Reviews 2013;18:1–5.
[11] Renewables guide, 2011. The six primary types of renewable energy. Available at: 〈http://www.renewablesguide.co.uk/primary-types-of-renewable-energy〉.
[12] Dopita M, Williamson R, editors. Canberra: Australian Academy of Science; 2010 Available at:.
[13] Bahadori A, Nwaoha C. Review of wind energy utilization in Australia. Journal of Sustainable Energy Engineering 2013;1(1):54–61.
[14] Yusaf T, Goh S, Borserio JA. Potential of renewable energy alternatives in Australia. Renewable & Sustainable Energy Reviews 2011;15:2214–21.
[15] International Energy Agency (IEA), 2010.
[16] Bahadori A, Zendehboudi S, Zahedi G. A review of geothermalenergyresourcesin Australia: currentstatus and prospects. Renewable&SustainableEnergy Reviews2013b;21:29–34.
[17] Kelly G. Renewable energy strategies in England, Australia and New Zealand. Geoforum 2007;38:326–38.
[18] Bahadori A, Zahedi G, Zendehboudi S. Anoverviewof Australia s hydropower energy:current status and prospects. Renewable & Sustainable Energy Reviews 2013a;20:565–569.
[19] Kent A, Mercer D. Australia's mandatory renewable energy target (MRET): an assessment. Energy Policy 2006;34:1046–62.
[20] Martin NJ, Rice JL. Developing renewable energy supply in Queensland, Australia: a study of the barriers, targets, policies and actions. Renewable Energy 2012;44:119–27.
[21] Australian Department of Resources Energy and Tourism, 2009; Canberra, ACT.: Australia.